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The Management Process, Management Information and Control Systems, and Cybernetics

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THE MANAGEMENT PROCESS, MANAGEMENT INFORMATION AND CONTROL SYSTEMS, AND CYBERNETICS

Zenon S. Zannetos and Jarrod W. Wilcox*

The purpose of this paper is to examine the impact of cybernetics on management of business organizations. If we define "cybernetics" as the science of control through communication, using the conceptual framework constructed by Wiener and modified by others,[1] then we can definitely find ample examples where cybernetic principles exert significant influence on management activities. Perhaps one may in the broadest sense consider cybernetics as a subset of management or possibly equate the two. For reasons which will become clearer later, we prefer to view cybernetics as a subset of management.

Despite this more or less definitional harmony, there is, however, a legitimate question as to what extent we can attribute such uses of cybernetic principles to the explicit emergence of this field of scientific pursuit. We can find evidences in the areas of managerial economics and managerial control where similar principles have been used implicitly for years, although typically not consciously. However, this does not detract

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[1] The framework puts emphasis on the information flows through the cybernetic system and on the way knowledge is utilized by such systems to gain their ends in a self-correcting manner.

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from the ultimate influence of cybernetics on management; as in many other areas of human pursuit, it is not so much the invention of new theories and principles which leaves its indelible mark on progress but rather the articulation and internalization of notions which previously have had only an unconscious empirical existance.

In order to develop our arguments we will (i) start with a conceptual framework which will enable us to link management of business organizations and cybernetics, (ii) indicate a conceptual representation of the managerial process and identify its major components, (iii) assess the impact of cybernetics on management across some of the most essential elements of managerial activities, and finally (iv) present some concluding remarks.

I. A Conceptual Framework for Relating Cybernetics and Management

In attempting to develop our framework we wish to distinguish between four kinds of entities:

1. Computational Machines
2. Cybernetic Systems
3. Organisms
4. Organizations

We will call devices which transform, after a time delay, sequences of changes in the states of input channels to sequences of changes in the states of output channels computational machines[2] or transducers.[3]

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[2] See Marvin Minsky, Computation, Finite and Infinite Machines

[3] See Ross Ashby, An Introduction to Cybernetics

One may usefully categorize such machines by the degree of fixity of state possibilities (finite machines versus Turing machine equivalents), by the degree of invariance in the relationship between input and output sequences (deterministic versus probabilistic), and by the degree of discreteness (discrete versus continuous).

The partially overlapping theories of automata,[4,5] information transmission,[6] and cybernetics [7] treat the various kinds of behaviors and design optimalities of certain subsets of computational machines.

In general, the more mathematically developed portions of these theories deal with rather abstract kinds of computational machines which, although internally consistent, do not allow us to get close enough to the detail of reality necessary for our purposes. We need a theory of computational machines physically embedded in an environment, where the combined system of machine and environment is subject to physical laws, particularly the law of non-decreasing entropy. When a computational machine through a flow of information is able in a self-correcting manner to gain and maintain for an appreciable time internal states which are not consistent with maximum entropy in such a reality-oriented environment, we will call it a "cybernetic system." When it can do so for an indefinite period in a non-artificial environment we will call it an "organism." This notion seems useful even though what we mean by "indefinite" and "non-artificial" is as yet imprecise.

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[4] See von Neumann, The Computer and the Brain

[5] See Minsky, op.cit.

[6] See Shannon, The Mathematical Theory of Communication

[7] See Wiener, Cybernetics

When such organisms couple together to form a conglomerate cybernetic system but retain an ability to decouple themselves and resume their independence we will call the conglomerates "organizations." Organizations may or may not behave as organisms.

While it is clear that all organizations involve organisms and in turn cybernetic systems and finally computational machines, organizations also may have properties not considered by the more basic theories. Thus one can expect to find applicability of cybernetics to management necessary, but such applicability may not be sufficient to either describe fully or "rationalize" the management process. In moving from computational machines to cybernetic systems we first necessarily encounter error, uncertainty, and environmental change. In moving to organisms we encounter a variety of so-called "irrational" behaviors engendered by limited capacities as opposed to an unlimited environment and by lack of unitary objectives. Finally, in moving to organizations we move to phenomena of culture, the gamut of social behaviors and interactive modes, and typically also encounter difficulties in reconciling conscious and unconscious interdependencies.

Accordingly, we must be very careful in relating the findings of cybernetics to the management of real-world organizations.

II. The Management Process

Managerial activity in business organizations includes both planning and control aspects. Specifically, it has been viewed as including:

1. Environmental analysis in order to assess the state of nature regarding both the external as well as the internal environment with which the organization is and will be dealing.
2. Determination of goals or alternative directions. Environmental analysis can provide some "vague" picture regarding the existing patterns of relationships. Through the application of some "normative criteria," a comparison between what appears to be and what should be is made, and through this comparison goals are derived for guiding the particular entity or organization. The word "vague" is used above because often it is not at all clear as to what is being exactly observed. And if what is observed is not very clear, obviously there can be no certainty that the criteria applied and the comparisons made are the ones most appropriate. Therefore, a process of iteration and sequential adaptation may have to take place before goals are derived.
3. Transformation of the goals into operationally meaningful propositions, and objectives for action. In other words, here are defined the strategies by means of which the goals and the more concrete objectives are to be achieved through operations (means to end chains).
4. Choice of the critical decisions and operations which are necessary for reaching the objectives and design of an

operational plan for execution. Part of the design of the plan involves planning of the organization structure. In addition, this step includes forecasting, definition of resource development activities, logistics, and budgeting as well as scheduling of the operations.

5. Choice of the signals or indicators which are necessary to inform management as to whether the execution of operations is according to the chosen plan and whether the chosen critical decisions and operations are in effect leading the organization to the accomplishment of its objectives.
6. Choice of the measurements which when applied to the results from operations will generate the signals mentioned in the previous step. The choice of the dimensions across which measurements are applied as well as the refinement of the measurements themselves and the size of deviation which will necessitate replanning and remedial action are determined by the sensitivity of organizational goals to the environment parameters, operations, and decisions being monitored.
7. Choice of the management information and control system which will apply the measurements to generate the chosen signals.

As will be noticed, the last three steps in the management process are mainly, though not exclusively, addressed to the informational output of the implementation of managerial plans, and as such refer to the

control process. The iterative and sequential nature of managerial planning and control is manifested in each of the above-mentioned steps. In practice, the process is also hierarchical, not only in its totality but also within each of the above major subactivities.

The above description indicates that the management process has the essential elements of a cybernetic control system. In fact, we have in the above seven steps a whole hierarchy of cybernetic processes. In order to simplify our exposition we will concentrate on the following three main elements of the management process:

A. Goal formation

B. Hierarchical structuring

C. Control

The question which we would like to ask is to what extent the past developments in cybernetics have helped management in each of the above key elements of the management process. In so doing, we wish to distinguish those areas of management where cybernetic principles and propositions have been applied in an operating sense from those where only philosophical benefit may have been derived. This distinction does not imply that theoretical constructs cannot be used to derive useful operational consequences or objectively varifiable hypotheses. Care must be exercised, however, so that we do not let our methodological purity lead us to models which are correct and viable within the limits of their assumptions but yet do not satisfactorily express reality.[8]

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[8] Richardson, "Imperfect Knowledge and Economic Efficiency," p.156.

III. The Impact of Cybernetics on Management

A. Goal Formation

If we look at the processes of goal formation, or its relatives criteria selection, generation of alternatives, and the assessment of the state of a complex environment, expecially when the latter is shifting, we will find that cybernetics has had little practical influence on management. The same can be said, however, for almost any other field of scientific endeavor with the partial exception of economics.

We have all heard predictions about cybernetic systems which would model themselves as well as the environment with which these interact and also model their perception of the process of interaction and model formation itself (for sequential adaptation), but such progress is not yet with us. The reasons for this, of course, is that we do not at this time understand all the complexities of the process of modeling and goal formation.

In terms of managerial reality, many management problems and thus management objectives are imposed upon managers by the economic reality of markets. The role of the latter in managerial goal formation has long been recognized. As Richardson pointed out, the invisible hand of Adam Smith is nothing less than the homeostatic control of society; "it acts as a method of communication, and by integrating the knowledge which is dispersed in many minds, enables society to work as a whole."[9]

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[9] Richardson, op.cit., p. 140.

Under the perfectly competitive model of entrepreneurial behavior implied in Adam Smith's framework, equilibrating prices are established through the unconscious interactions of the markets and within such markets. These prices serve under the hypothesized conditions as the only information necessary to motivate the entrepreneur to allocate resources efficiently (profit maximizing). One need not examine the "internal structure" of the entrepreneurial organization or the decision making processes of the entrepreneur because the market enforces universal rationality. But the perfectly competitive model, under which the market served as the cybernetic control system, put emphasis on the result of the process, not the process itself or method of adjustment to disturbances.[10] Because of this emphasis the theory of managerial planning and control has been neglected until recently; so also has been the study of individuals and organizations as information processing entities.

If we step back and look at the processes of adjustment, of necessity we must examine the relationship of the individual or the organization to the outside world. Then we find that we must develop models and hypotheses which state explicitly the critical causal connections, of paramount significance among which will be hypotheses about how the individual and the organization learn from experience.[11] Underlying the main hypotheses there are others on how perception occurs, on the type

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[10] See von Hayek, Simon, March & Simon, Cyert and March among others.

[11] See von Hayek, "Economics and Knowledge."

of filtering which is characteristic of certain organizations and individuals, on the way problems are structured and decomposed, and on the process of association, selection and use of incomplete information in solving the perceived problems.

Even when enough is known to predict the adjustment behavior of individuals, this does not imply that we can necessarily predict the behavior of the organization of which they are components; the reverse is also true. Organizations like the perfect competitive markets reach their equilibrium somehow by the use of the bits and pieces of information which are processed by individuals. Again, we have learned that knowledge of how the individual adjusts and reaches his goals is not enough to provide a prediction of how the organization behaves under similar situations unless we know also how these information processors are inter-related.

This gradual emergence of our understanding of the importance of viewing economic and business activity in terms of dynamic organizational adjustment under conditions of uncertainty is no doubt partly a result of the emergence of the field of cybernetics.

The necessity of understanding the process of adjustment of organizations is even more critical when we are dealing with oligopolistic and monopolistic situations. Characteristic of the latter is the degree of conscious interdependence among organizations. In managerial planning, therefore, no longer we can afford to consider competitive behavior as part of an uncontrollable given environment to which the organization

reacts. To be effective, managerial planning must include sophisticated environmental appraisal and prediction of the competitors' reaction to an initial action by the organization. Cybernetic notions have provided an important philosophical stimulation in the efforts of management scientists who are attempting to derive organizational goals in situations characterized by oligopolistic and monopolistic competition. Essential elements of the transactions of an organization with its environment can be modeled in terms of higher order cybernetic control sytems.

Thus in the area of goal formation and related processes, cybernetics has made some philosophical contribution to management. In our estimation the impact of cybernetics would have been much greater if it were not for certain historical accidents.

The history of cybernetics as a field has been marked by a core of careful, serious science surrounded by a colorful penumbra of speculation and loose analogies. Within this penumbra a number of cultural values have grown up which seem to us to have no solid base in either theory or practice. Two of these relate to the process of goal formation.

1. Confusion about the relationship between entropy, information, and cybernetic control.

Many writers have pointed out the apparent connection between the notions of information and negative entropy. Properly understood,[12] this relationship indicates a basis for a comprehensive theory of organisms.

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[12] See Brillouin, Scientific Uncertainty and Information

Improperly understood, "entropy" is a worse than useless concept which obscures practical application of the cybernetic approach. Consider the following quoted remarks.[13]

> Suppose that the two sub-systems both begin with the same amount of energy. Sub-system A uses up a lot of this energy in the process of organizing itself internally. Sub-system B uses up less of its energy in the process of organizing itself to a lesser extent. So A is more organized, and more depleted of energy, than B. Accordingly, since interaction occurs, energy must, by the rules of entropy, flow from B to A. It is now, as it were, too late for B to catch up in degree of organization with A. It has a decreasing supply of energy available to use for organizing itself, while A has an increasing supply. So the more organized A feeds on the less organized B. Eventually A will destroy B altogether (in an isolated system). Note that the boundary of A, which is its interface with B, has to be visualized as advancing into B's territory. That is, the degree of organization moves against the direction of the flow of energy.
>
> Now the business of self-organization becomes finally clear when it is realized that a system has to be recognized as being organized when in its most probable state. A prime example of this occurs in the process of growth. A seed has to be considered as a variety-amplifier, for it carries the specification of something larger than itself. But it also carries a temporally-based plan for growing to maturity: a self-organizing capability. Not only does this plan specify a set of architectural relationships, it specifies a criterion of maturity. That is, any organic seminal programme that inaugurates and controls growth 'knows when to stop.' This capability applies not only to the macrostructure, so that you and I are roughly the right size to be recognizably human; it also applies to the infrastructure of the organism: every limb, every organ, every parcel of tissue however delineated, from cranium to toe-nail, grows to a limit. During growth, further growth is by definition due to follow; development (except by massive intervention from outside) cannot be arrested until the plan is complete. To this extent, a partly-grown organism is in an improbable state, and is driving towards its most probable state--adult completion. Growth can be regarded, that is to say, as an entropic process. The growth process stops when the genetic information is used up, actuality having been finally and in sum exchanged for potentiality. Any form of the entropy equation will serve to formalize this process. Growth, then, is a self-organizing activity of a system in which that system 'learns to be what it is.'

[13] Stafford Beer, Decision and Control: The Meaning of Operational Research and Management Cybernetics, p. 347; p. 360-61.

From the point of view of business organization, conclusions that there is a simple transformation between energy and structure, that organized states are most probable, and that a maturing organism represents a mere unfolding of the structure inherent in its "seed," are not only of limited usefulness but also discouraging. Clearly, organized states are most probable, given self-correcting and self-organizing properties of the organism which are inherently biased toward such states, but this is a probability itself conditional on an unlikely event, the existence of these properties. Without them, the most probable state of nature in business management, is stagnant mediocrity and ultimately bankruptcy.

In the area of management goals cannot be considered as fixed. Innovation is the life-line of business organizations, although such innovations may initially increase the entropy in the total entity. If we were to accept fixity of goals as a fundamental premise of cybernetics, we would then have to relegate cybernetic influence only to the control of operations. Operational control systems are homeostatic but we hope that over time the goals change. Maturation of organizations consists partly of the incorporation of negative entropy extracted from the environment rather than merely the disposition of existing resources.

A more useful and correct notion for management is to regard "knowledge," or more broadly speaking, "resources," as that which enables a cybernetic system to reduce its own entropy, "information" as additions to knowledge, and "cybernetic control" as the process by which a cybernetic system utilizes this knowledge.

2. Over-reliance on random, as opposed to selective, self-organization.

A popular notion in the field of cybernetics is that of "requisite variety."[14] A cybernetic system seeking to control disturbances of great variety must itself be of great (requisite) variety. One way this variety can be generated is through random mutation and search. Such procedures are, however, inefficient as compared to those which can utilize even very limited knowledge of the search space.

We have come to appreciate the limitations of such purely random adaptation through sober experience with the "Perceptron" and similar efforts.[15] If we wish to develop the capacity to cope with very high-variety disturbances, and to accomplish it within a time reasonable for the necessary action, we must use selective search or adaptation. Stafford Beer has proposed setting fast machines to work trying at random until they get acceptable solutions as a practical means of controlling complex industrial processes.[16] Such purely random control is likely to find limited application in industry not only because of the urgency of decisions but also because in many cases goal-oriented search can yield simple heuristics for "pruning" the alternative action trees. Even though Beer proposes a two-part machine one of which vetoes (selects) among random proposals of the other, he nevertheless still faces the basic problems of explosive alternatives. True, he has saved the human having to explore many of the random proposals, but the machine still must go through an unselected set

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[14] Ross Ashby, Introduction to Cybernetics, p. 206, p. 245.

[15] Marvin Minsky, "Steps toward Artificial Intelligence," in Computers and Thought, Feigenbaum and Feldman.

[16] Stafford Beer, Cybernetics and Management, p. 136-148.

of possibilities. A fact that is often overlooked is that the computer, in spite of its speed, may still find this set too large to handle within a practical time span. For example, it has been estimated that a random search for the best opening move in the game of checkers might entail checking on the order of perhaps 10^{40} move sequences, which, at three choices per millisecond, would still take 10^{21} centuries to consider.[17] These astonishing figures suggest that even for somewhat simpler tasks, it would be wise for the designer of such a machine to build in as much knowledge as practicable to be utilized not just to veto random proposals, but to guide in the generation of non-random proposals. We do not suggest complete elimination of randomness even if it could be achieved; we strongly believe that a degree of randomness is useful for challenging established thought processes and solutions. But this is a good example of the need to carefully check the simplified assumptions on which a theoretical result is based against the demands of practical application.

B. Hierarchical Structuring

One of the notions which has had a tremendous impact on the practice of management is that of an organizational hierarchy with its concomitant substabilities. At first the progress through the utilization of these notions has been unconscious, hence passively accepted and evolutionary. When, however, organizations grew out of the small-scale entrepreneurial

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[17] A. L. Samuel, "Some Studies in Machine Learning Using the Game of Checkers," in Computers and Thought, Feigenbaum and Feldman (Eds.)

fold to the degree of complexity represented by large-scale oligopolistic and monopolistic environments, crises enforced a re-examination of both the process of evolution and the principles embodied in the various organizational configurations. It was out of such soul searching on the part of both practitioners[18] and "students" of management that the role of hierarchical structures with articulated substabilities started to emerge. The soul searching and the need for progress are by no means over. It is our belief, however, that a strong foundation for sustained progress has been set once the profession has realized that organizational structures can be included and used as an active managerial tool as well as resource. So no longer do we leave the design of organization structures to crises which emanate out of the transactions between the organization and its environment, nor do we accept that there exists an immutable natural homeostatic state to which organizations must be allowed to gravitate. This does not deny, however, the usefulness of homeostatic principles in the definition of the substabilities which are hierarchical and a part of a larger organizational hierarchy.[19]

Hierarchies are found useful in business practice in the areas of both planning and control. We find that nearly all problems of practical interest, whether conceptual or operational, have to be partitioned and hierarchically structured for solution. Some of the major reasons for

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[18] Chester Barnard was among the first to do so in his Functions of the Executive.

[19] If at any time we reach the undesirable hypothetical state where the whole business organization is a huge homeostat both in the planning and operational sense and such homeostat can be duplicated then we will have reached stagnation.

such partitioning are:[20]

1. Cognitive limitation of the intelligent organisms which does not allow (a) operation on too many variables at a time and (b) adequate specialization across all dimensions of the problem. The organism therefore must depend on a substability for an appropriately preprocessed and timely input.
2. Intelligent organisms associate by transferring knowledge from an area of expertise to a novel situation requiring solution. In the process they become specialized.
3. Partitioned structures possess survival characteristics which allow them to save many parts in case of failure.

Hierarchical arrangements allow the partitioned organization to achieve an effective balance between centralization and decentralization by considering issues such as:

1. environmental and resource interdependencies between units which argue for co-ordination or decoupling of their activities by a higher level;
2. benefits from relative decentralization of subordinates such as learning returns, especially in an uncertain environment, and motivational effects;
3. benefits from relative centralization such as a reduction of the number of transformations of objectives and thus of potential

[20] For a more elaborate discussion of these issues and their implications for centralization, decentralization, standardization, and the process of innovation, see among others: Schumpeter, Simon, Z. S. Zannetos and O. Poensgen, and Zannetos, "On the theory....."

of undue diversion of organization activities toward the satisfaction of local objectives having little bearing on underlying basic organizational objectives;

4. communication requirements and costs necessary for the coordination and control of units centralized from without operating in an uncertain and changing environment; and
5. capacities and costs of the individuals making transformations of objectives.

Perhaps because the developed mathematical tools begin to falter when dealing with very large and complex systems, but more likely through a lack of appreciation for their importance, hierarchies of planning and control have not been emphasized in some parts of cybernetic literature. Hierarchies have been acknowledged as "speeding up" the action of large, complex homeostats, as in the control of the firm[21] and more recently in the structuring of computers. Although we see ample evidence of hierarchical structuring of software, we believe that the failure to consider some of the fundamental notions underlying relatively decentralized hierarchical structures has contributed extensively to the present rather sad state of software management.

Going further, we believe that hierarchies are essential to the reduction of search spaces in most problems of practical interest.

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[21] Stafford Beer, Decision and Control, pp. 378-391.

Hierarchical plans, incorporating hierarchical means-ends trees, can reduce action spaces in a similar fashion.[22] Also, for reasons to be indicated more fully later, hierarchies are useful in learning. In applying the strategy of simple reinforcement to a complex control mechanism, we encounter a serious difficulty in distributing credit for success of a complex strategy among the many components involved, and thus inhibit causal diagnosis and learning. This difficulty can be managed by arranging for local reinforcement of partial goals within a hierarchy and by grading the training sequence of problems to parallel a process of organizational maturation. Similarly, a hierarchy of perceptual constructs reduces complex detail, implicit for example in our vision, to a simplified version that higher-order cognitive processing can handle.

C. Control

It is in the area of control of operations that cybernetics exerts a significant and undisputed influence. Today so-called cybernetic controls manage or help manage large chemical processes, provide automatic quality control, facilitate traffic flows, schedule freight cars and many other operating processes. In this sense managerial functions have been taken over, redefined, or upgraded with the aid of cybernetics. The relatively sophisticated command and control systems used by the military and by NASA whet our appetite for use of such techniques in

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[22] Newell and Simon, "GPS, A Program That Simulates Human Thought," Computers and Thought.

controlling not just operations, but the planning process itself. For the latter, management could use help particularly in pattern recognition and causal diagnosis.[23]

Clearly one of the most obvious applications of cybernetics to management is in the area of servomechanism control. The business organization's partial knowledge of its changing environment creates many disturbances which must be corrected, some on a continuing basis. Where relatively stable organizational resources exist for coping with disturbances of relatively stable or predictable frequency distribution (or probability distribution), straightforward analytical methods exist for the working out of optimum policy parameter values.[24,25] Unfortunately these methods tend to break down for complex non-linear control situations, and one is driven to computer simulation[26] as an analytical tool.

If one confines oneself to systems of moderate complexity one can utilize the conceptual framework of servomechanism theory even where its mathematical techniques are intractable. One may usually construct a simplified model of systems of even great complexity which captures enough of the system's nature to be interesting and useful. Further, the notion that all decisions may be viewed as embedded within

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[23] For some of the problems involved here see, Carroll and Zannetos, "Toward Intelligent Management Information Systems."

[24] Wiener, Cybernetics

[25] H. A. Simon, "On the Application of Servomechanism Thoery in the Study of Production Controls," Econometrica, April, 1952.

[26] Jay Forrester, Industrial Dynamics, 1961.

feedback loop systems is a powerful tool for exploring organizational structure, even when the frequency spectra of the disturbances to be controlled are too little known or too unstable to permit "optimal" design. Fruitful design improvements may result from even very limited information, given an understanding of characteristic feedback system behavior. Often the incorporation of new channels of information into important decision processes will markedly alter the dominant modes of behavior of the system.

Unfortunately, in the area of cybernetics proper, there seems to have been so far an over-reliance on "black-box" input-output analysis; this over-emphasis on "behavioristic controls" has so far limited the applications of cybernetic principles in the area we feel the contribution can be of the greatest value.

The characteristic mode of analysis employed by Wiener utilized as a complete description of a transducer its input-output relationship. This "behavioristic" or "black-box" analysis is sometimes suggested for use in practical management situations.[27] There are several reasons why purely behavioristic analysis, as opposed to at least some structural-functional analysis of the parts of a transducer, may not be preferred.

In many practical situations one can realize an orders of magnitude gain in efficiency if the knowledge gained in other situations is incorporated into the analysis. Thus, for example, it may be that most transducers of interest are constructed from parts whose behavior and

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[27] See Stafford Beer, Cybernetics and Management.

structure is already known. Thus if we can efficiently identify such parts in action within the transducer, we do not have to re-learn the input-output relations for each part, and further, we can more efficiently analyze the input-output relationship for groups of parts to determine the way in which these parts are related. In addition, through this functional analysis, we may gain knowledge about new parts which can be generalized into new transducers.

Benefits such as those described above provide the main justification for using articulated models which can be used to fit more than one situation. Of course, there are limitations on the efficient use of such articulated models. The transducer for instance may be too novel, or too elemental, or the invariance of the input-output relations for the whole transducer may be more assured than the combination of its parts or, indeed, of each part individually.

In general, as we have already intimated, there will be a trade-off which in most practical situations argues for a mixture of the two modes of analysis. Whenever pure behavioristic analysis is possible, one must ask if such an approach is efficient. In dealing with complex organizations as transducers, one often finds that many orders of magnitude separate the time required for a purely behavioristic approach from that required for practical results.

In addition, we have cases of practical interest in organizations where pure behavioralistic analysis is not only less efficient but impossible. Let us suppose for instance, that the transducer undergoes

occasional change. If the transducer is complex, one may not be able to amass long enough sequences of input-output data to determine adequately the transformation applied by the transducer before its nature is changed; but the sequences might well be long enough to determine adequately the relationship through structural-functional analysis. Of course, when we deal with cybernetic systems, as opposed to computational machines, the changing environment implied by conditions of increasing entropy makes the observation of extremely long non-trivial sequences very unlikely.

What we argue is for a proper balance between behavioristic and structural analysis. The needs of intelligent managerial systems require causal diagnosis and heavily favor functional systems. In this we feel that the study of complex real-world transducers with great internal "memory"[28] must of necessity employ analysis of their parts. Often, however, we may find that initially our only alternative is behavioristic control, and we must therefore use it as means to the higher end of more generalizable knowledge.

IV. Some Concluding Remarks

In this paper we have attempted to analyze the strengths and weaknesses of the cybernetics approach as applied to management. Our conclusion is that cybernetics can serve not only as a conceptual-philosophical aid but also as an operational tool in both managerial planning and control, but that so far, most of its promise is yet unrealized. This

[28] Marvin Minsky, Computation, Finite and Infinite Machines.

is especially true in the planning sphere. Only in the area of control of operations has the impact of this promising field shown tangible results.

There is evidence, however, that the cybernetic sphere of influence is gradually expanding. The work of H. Simon and his associates, Soelberg's work in the area of sequential thought processes,[29] and the work in the area of artificial intelligence software, some of which is applicable for management, are typical examples of this expanding influence. Within the Managerial Information and Controls Group at the Sloan School of Management at MIT we started a small project two years ago in an effort to understand how people plan goal oriented search, and how they sequentially adapt on the basis of experience in the context of student learning. The results of our experiments so far are encouraging. Our ultimate goal is to develop educational systems which integrate basic educational material, and guide the student toward the most efficient search path once his goal is recognized. But in order to reach our goal we must first understand the process of transformation of goals to operation objectives, decisions, operations, etc. as described in our discussion of the management process. In other words, we must learn how "trees" of means to ends are generated, generalize on the basis of the common elements of successful searches and then build systems which aid this planning process. In the broad sense, this is the same process which we must understand if we hope to improve the management planning process.

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[29] Peer Soelberg, "Conclusions from a Study of Decision Making," Working Paper 173-66, Sloan School of Management, MIT.

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